United Nations Industrial Development Organization

Distr.
LIMITED
ID/WG.441/5
5 June 1985
ENGLISH

First Expert Group Meeting on Computerized Maintenance Systems in Metallurgy *

Prague, Czechoslovakia
28 January - 1 February 1985

SOME SPECIAL ISSUES OF DESIGNING COMPUTER-AIDED MANAGEMENT INFORMATION SYSTEM FOR STEEL WORKS MAINTENANCE SERVICE **

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* Organized by the United Nations Industrial Development Organization (UNIDO) in co-operation with the Institute for Automation and Industrial Management (INORGA-Prague) under the auspices of the Czechoslovakian Ministry of Metallurgy and Heavy Engineering.

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*** GKES (State Committee for External Economic Relations, USSR

V.85-27416

1. Introduction

Automation and computer control of steel works maintenance service is a problem of almost the same importance and actuality as manufacturing process control itself. This can be concluded only from the fact that considerable reduction of opeeating facilities emergency shutdowns is anticipated through Computerized Maintenance Management Systems /CMMS/ implementation. For example, at Eastslovakian Steelworks /VSŽ, Košice, CSSR/ this innovation resulted in half decrease of downtime.

VSŽ scored big successes in the development of computer-aided management information system for steelworks maintenance service. Examination of this system by the team of Sovie professionals showed economic advisability of implementation of such systems in the USSR. Czechoslovakian recomendations on this topic are highly valuable for Soviet counterparts.

The USSR also obtained some experience of computerized problem solving for management of the maintenance operations, and this experience permits making a conclusion that supply with standard spare parts /subassemblies for operating facilities/ is the most critical problem to be considered first of all. This paper describes the problem in detail.

2. Special Features of Maintenance Process Control in Terms of Equipment Standard Components

Controlled plant of CMMS includes the following units:

1/ all enterprise equipment to be maintained,
2/ all repair shops which manufacture and recover spare parts,
3/ all warehouses which store spare parts inventories and materials required for maintenance processes.

One peculiarity of CMMS stems from its comprehensive nature since units under repair can appear to be mechanical equipment as well as electrical and power facilities.

Such comprehensiveness might lead one to low spirits provided one forgets that common rules exist for maintaining all types of operating facilities. Therefore, software of CMMS is universal as programs are independent of controlled unity type. All differences are defined by a behavior of any certain element whether it is mechanical, electrical or power-supplied, and dissimilarity in behavior produces different management rules.

2.1 Classification of Equipment Components

To expose the above mentioned differences of equipment components may be classified as follows:

1/ Replaceable versus unreplaceable - depending on whether or not a component is replaced when repaired.

Basically, replaceable components include large subassemblies which should be treated as an integral part of mechanical construction to be repaired in-place using different materials.

A replaceable component may be substituted by a similar one which previously existed as a stand-alone unit and was treated as a spare part of a production equipment.

2/ Recoverable versus unrecoverable - depending on whether or not a component becomes operational again after the repair.

A recoverable component when repaired after a wear-out or a failure can perform its functions within a production unit of equipment as before if proper recovery operations are carried out.

Unrecoverable failed component must be removed from a production equipment since its functionality cannot be recocered.

Unreplaceable component, obviously, must be recoverable, otherwise the production equipment unit would fail as a system after a failure of a single component. Replaceable components can be both recoverable and unrecoverable. Increase in a percentage of former ones improves economic figures of the production equipment performance.

3/ Standard versus nonstandard - depending on the range of usage as applied only to replaceable components.

A dedicated nonstandard component may serve as a spare part for a single production equipment only. It is constructed exclusively in connection with a given equipment, manufactured originally together with this one, and then produced repeatedly for supporting its recovery.

Standard components have a wider range of usage, for they can serve as spare parts of several equipment items. Their universality is defined by availability of different type components with different characteristics.

Designing and manufacturing of standard components are not associated with the development and manufacture of equipment units where standard components are used as spare parts. On the contrary, the last ones become building blocks of the former ones if required types of standard components are available.

Fig. 1 shows a classification tree for equipment components together with symbolic notation of different categories of replaceable components /spare parts/. This notation is used in a scheme of component movement route /see Fig. 2/. A colored symbol means operational unit, an uncolored one corresponds to a failed unit.

2.2 Behavioral Peculiarities of Equipment Standard Components

Analysis of various categories of equipment components on a behavioral level allows to expose some important peculiarities in terms of choice and statement of control problems for a maintenance management.

1/ Inventory management problems for standard and nonstandard components.

The wider a range of usage of a given type spare part, the more its required quantity and the better opportunities exist to control its inventory level. Standard spare parts batch manufacture by specialized factories expands these opportunities.

The multiple usage of standard spare parts involves availability of a special function within maintenance process control system connected with spare parts inventory allocation to users /denoted as "Al." on the Fig. 2/. Since standard spare parts may be used for different repair operations /on different equipment items/ they must be issued from stocks in accordance with their priority and a specified completion date.

As with nonstandard spare parts, they are of individual nature and so a flow of components is meaningless. It is possible to manufacture them only on user demand. The stocking of such components is unjustified and their manufacturing must be planned in connection with proper repair operations.

2/ Problems of reporting and analysis of equipment state are different for nonstandard and standard components.

For a total maintenance process a matter of great difficulty is the acquisition of data sufficient for statistical analysis in particular for the sound choice of proper cycles of equipment technical inspection and preventive maintenance.

EQUIPMENT COMPONENT CLASSIFICATION

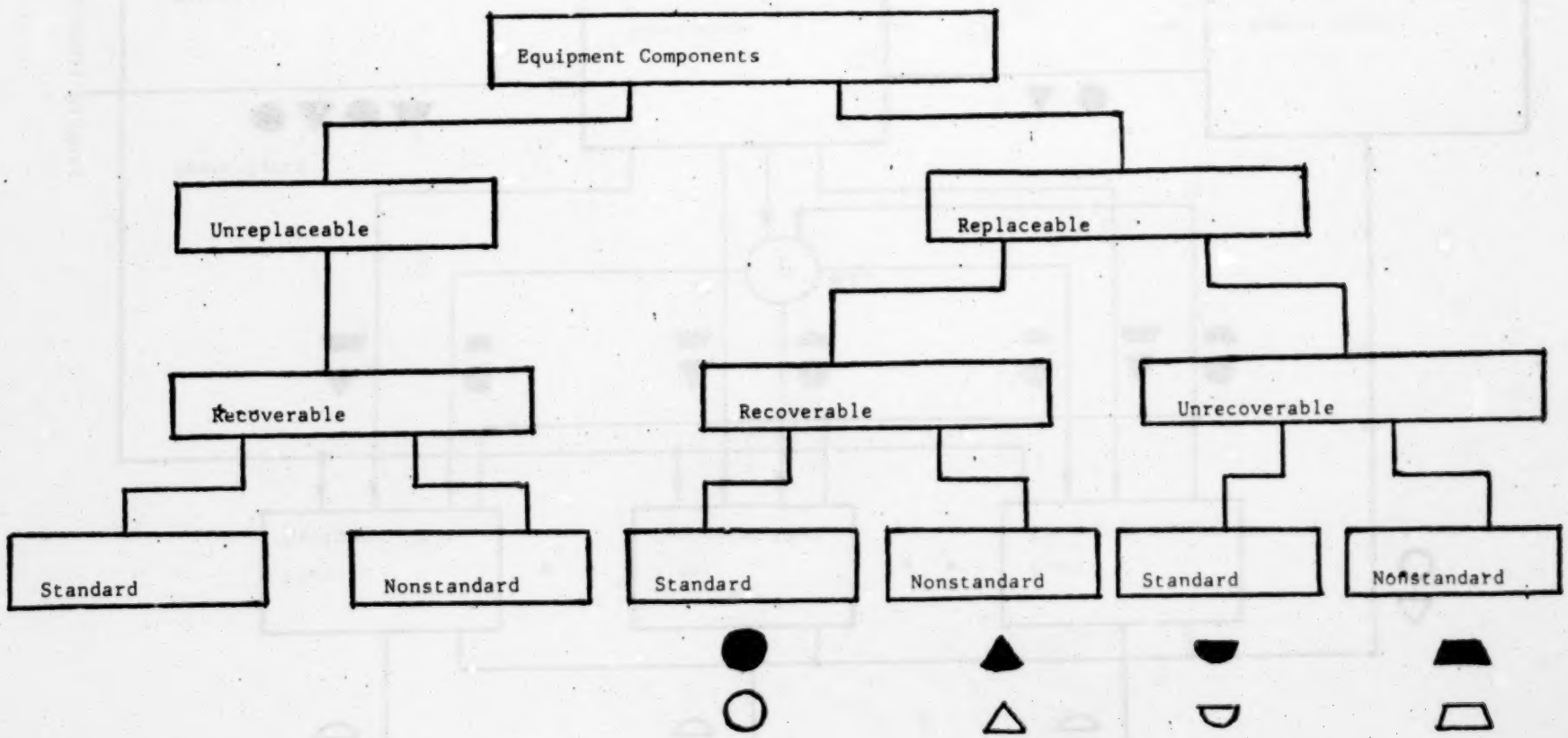
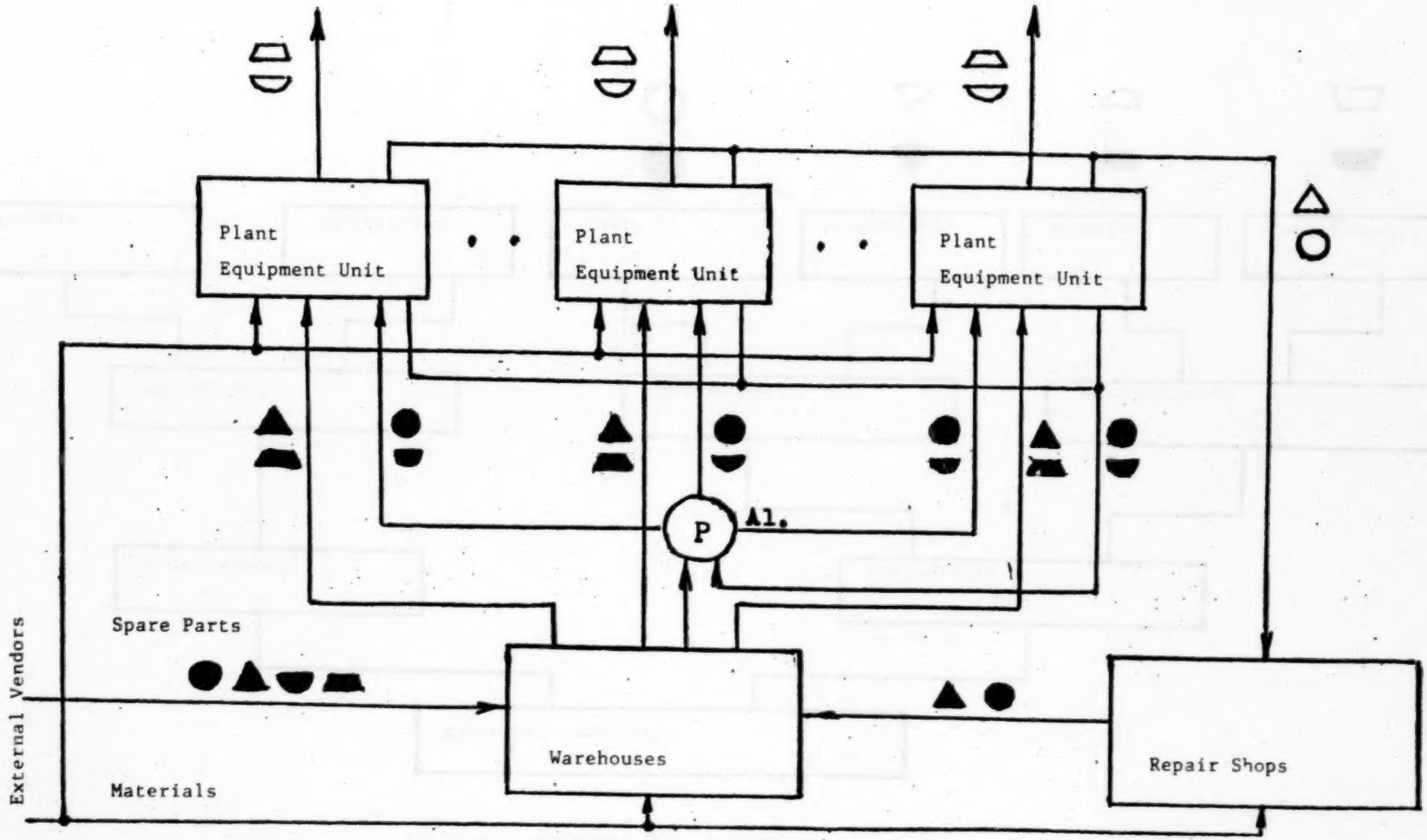


Fig. 1

EQUIPMENT COMPONENTS ROUTE



Difficulties of statistical data acquisition stem from the fact that failures of components occur rather seldom. And here standard components are in a better position as they are intensively used, and therefore a total flow of failures over the plant has a high rate that facilitates statistical evaluation.

To make this evaluation feasible it is necessary:

- to enter into the computer system failure data, identifying type and cause of failure with accuracy to a component of the equipment;
- to create a data base of such data and to execute their statistical processing.

3/ For replaceable standard recoverable components there exists a special problem of recording equipment components movement route.

Unrecoverable components are removed from an equipment in a case of wear-out or a failure. As with recoverable ones, they are routed after withdrawal to repair shops to be recovered, then go to a warehouse and finally are mounted into the equipment under repair.

Thus recoverable components perform cyclic relocations within a plant. A reliability of every component depends on its current cycle, while its availability for usage is defined by a certain phase of a cycle. This involves reporting of recoverable components movement. The problem is particularly important in connection with standard recoverable components in terms of their allocation to equipment items, since components in stock have to be allocated as well as those in the process.

4/ Controlled stores of standard components may include components in stock as well as reserve ones at production facilities.

Since it is necessary to provide a highly reliable performance of equipment items, reserve spare parts have to be available on the spot to remove quckly the failed components.

On the other hand, shutdowns of production equipment are not allowable on account of standard components stock-out, while they are available at some other equipment. Therefore, floor stock standard components may be allocated to different equipment items under repair as well as similar in-stock ones.

It is used to believe that standard components with discussed peculiarities take no more than 10 % of the volume of all spare parts both by nomenclature and by quantity. So these peculiarities are usually neglected in the CMMS development by their orientation primarily on the rest 90 % spare parts, i.e. on nonstandard components.

From our point of view, the role of standard spare parts in maintenance process is more serious than their relative volume, and it is precisely this fact which shows clearly the advantages of computer-aided maintenance management.

3. CMMS Functions Related to Equipment Standard Components

CMMS functions can be categorized into three areas of activity:

1/ "Equipment" area which includes testing and analysis of equipment condition, technical inspection control, and management of repair process.
2/ "Inventories" area which includes purchase orders releasing, control of spare parts receipts, as well as reporting and allocation of their on-hand inventories.

3/ "Production" area which includes process setup, production planning and reporting, and spare parts recovery.

The first area consists of 5 subsystems:

- Equipment Shutdown and Failure Accounting
- Equipment Units Movement Reporting
- Management of Equipment Technical Inspection
- Equipment Maintenance Planning
- Management of Equipment Maintenance

The second area consists of 3 subsystems:

- Release and Reporting of Spare Parts Purchase Orders
- Spare Parts Central Warehouse Control
- Spare Parts Inventory and Allocation

The third area includes 3 subsystems:

- Process Setup and Spare Parts Recovery
- Planning of Spare Parts Manufacturing and Recovery
- Decision Support Information System

Peculiarities of standard components control discussed in Section 1 are exposed within three subsystem of the first two areas.

3.1 Equipment Shutdown and Failure Accounting Subsystem

This subsystem of "Equipment" area performs two functions:

1/ Downtime and failure recording
2/ Statistical processing of failure data

The first function results in monthly reports of shutdowns and failures including cumulative daily data which are grouped due to production equipment items, failure categories, causes

of failure, etc. This is necessary for taking organizational and taechnical measures to improve equipment operation reliability.

The second function associated directly with standard components which, as mentioned in Section 2, give some opportunities for acqusition of sufficient data for statistical processing.

The subsystem of interest generates proper data file and calculates benefits as follows:

1/ Time interval between two successive failures
   /to define MTBF/
2/ Number of failures at a certain time period
   /to define a failure hazard rate/

The first parameter allows to establish equipment technical inspection and preventive maintenance cycles. Both parameters are used within three other subsystems of "Equipment" area. Technical inspection cycles become a background for development of proper weekly schedules with the indication of checking operations to be carried out by each inspector during the working shift.

Preventive maintenance cycles are used in a planning subsystem as a background of annual monthly maintenance schedules, which define due data and repair type for each equipment unit.

MTBF is used also in maintenance management subsystem to prepare operating instructions for a certain repair and to estimate spare parts requirements. These documents suppose a planned replacement of spare parts highly prone to failures.

The second parameter permits determination of a standard spare parts requirements per year and is used for calculation of their optimum inventory level.

The optimum inventory level becomes in its turn a basis for a release and accounting of replenishment orders within a proper subsystem of "Inventories" area. This subsystem performs spare parts purchasing on a basis of requirements of maintenance service. Conformably to nonstandard spare parts demand is defined by a repair schedule.

As with standard spare parts, another ordering policy can be applied here, namely the one based on inventory level control /see Section 2/. The lot size to be purchased in this case is defined by on-hand stock optimum inventory level.

To solve the above mentioned problems it is not sufficient to know expectances of all variables under consideration alone. For the minimization of emergency risk it is necessary to perform condition checking and replacement of unreliable components before its probability of failure becomes significant. Therefore, actually one has to deal with probability distribution and to solve a state estimation problem using small volume samples and arther sophisticated mathematical statistics techniques.

A numerical calculation of given parameters for specific equipment elements requires availability of input information that contains description of failures, their types and causes with an accuracy to a detail of equipment unit. This accuracy exceeds significantly the first subsystem requirements /shutdown and failure accounting requires an accuracy to a specific equipment unit/.

3.2 Equipment Units Movement Reporting Subsystem

This subsystem of "Equipment" area performs a function of replaceable standard element movements recording.

As mentioned in Section 2, each standard component of a given category can be in the following states:

1/ In the operation condition within the equipment
2/ In equipment unit on-site floor stock
3/ In a recovery process at a repair shop /this state may be further detailed according to the considered phases of recovery/
4/ In operational state at the varehouse

Components in states 2 to 4 form a stock available for allocation to different repairs. In this case components in states 2 and 3 require a prediction of transition time from those states to the state 4.

To make such an approach feasible the subsystem stores information on timing of mounting each component into the equipment /together with the definition of operating or reserve state/, as well as on timing of their removal. Information on recovery progress in a repair shop is delivered by the "Production" area and consists of the following components:

1/ Recovery setup progress messages from the Process Setup and Spare Parts Recocery subsystem
2/ Messages on due dates of recovery operations fulfillment from the production planning subsystem
3/ Messages on actual progress of recovery operations from the Decision Support Information System

The subsystem output data contain information on inventory levels and support decision making in their allocation to production equipment units to be repaired.

Equipment Units Movement Reporting subsystem belongs to "Equipment" area, although within "Inventories" area there exists a similar Spare Parts Inventory Accounting and Allocation subsystem, but the last concerns only the central

warehouse inventories.

As with considered "Equipment" area subsystem most of its controlled inventory is a floor stock of components at equipment units, so its basic allocation decisions involve transfer of components from one unit to another.

To make such specific decisions feasible each component at any state within a controlled plant must be supplied with a unique identification code. Nonstandard component item code indicates its position in a hierarchical structure "equipment - assembly - subassembly - ... - component". For a standard component that changes its location in the structure, such approach is not acceptable and other identifier is needed, without dependence on location within an equipment, for example, a sequential item number.

3.3 Spare Parts Inventory Accounting and Allocation Subsystem

This subsystem belongs to "Inventories" area and performs the following functions:

1/ Reporting of spare parts availability and movements
2/ Generation of data for stocking and allocation of spare parts inventory to users

The first function involves providing information on available inventory at a warehouse as well as receipts and issues of spare parts at or from stock for both nonstandard and standard ones.

The more interesting second function concerns only standard spare parts /see Section 2/ and becomes active as soon as warehouse receives user requisitions for spare parts delivery.

To make a reasonable decision on a lot size to be delivered to a given user one must take into consideration the following information:

1/ Available spare parts at a warehouse
2/ Anticipated delivery of spare parts by external or internal vendors /for purchased and manufactured by own repair shops components accordingly/
3/ Predicted spare parts usage both by a given and other users

The main management goal is timely and complete supply of required spare parts to all repairs indicated in user requisitions. Furthermore, the forecasts of spare parts usage by each equipment unit should be produced in a form of a maintenance schedule, indicating spare parts requirements for every specific repair.

Such on-demand policy of spare parts allocation involves inevitably their prior assignment /stocking/ to anticipated demand. The stocking may cover both on-hand and on-order inventories.

Receipts/issues data are available from the central spare parts warehouse information subsystem operating within "Inventories" area. On the other hand simultaneously forecast availability of purchased components from external vendors could be estimated according to planned and closed purchase orders. This information is available from Release and Reporting of Spare Parts Purchase Orders subsystem within the same area.

Forecast availability of spare parts produced by repair shops of the plant can be derived from production schedules generated by the spare parts production planning subsystem, and from actual manufacturing process data delivered by Decision Support Information Subsystem. Both subsystems belong to "Production" area.

The above mentioned forecast of spare parts usage is derived from a maintenance schedule generated by the Equipment Maintenance Planning subsystem, and from actual spare parts usage data generated by Equipment Maintenance Management Subsystem. Both of them belong to "Equipment" area.

It is interesting to note that a problem of standard spare parts stocking and allocation is quite the problem which combines practically all CMMS subsystems of three areas into a unified system referred to as Integrated Maintenance Management System. The similar integration is attained due to Equipment Units Movement Reporting Subsystem /see Subsection 3.2/, but not so much.

In the environment that excludes existence of the two subsystems all three areas can perform their functions independently, if operating personnel will generate spare parts purchase and manufacture orders. Consequently, Spare Parts Reporting and Allocation Subsystem may be treated as an integrating superstructure upon other CMMS subsystems.

4. Conclusions

This paper permits to make the following conclusions concerning techniques of problem solving for some problem areas of CMMS at steelworks:

1/ Equipment shutdown and failure data must be detailed to the level of a specific component of an equipment unit.
2/ Statistical data processing is necessary for a calculation of such parameters as MTBF and hazard rate for different equipment components.
3/ Standard recoverable components movement reporting must be carried out to generate information required by the problem of allocation these components to repairable equipment items.
4/ It is necessary to solve a problem of standard spare parts stocking and allocation to repairable equipment items.